



UNITED STATES AIR FORCE RESEARCH LABORATORY

Development and Testing of a New Reefing System to Reduce Parachute Opening Shock Characteristics During Seat Ejection

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FOR THE DIRECTOR


F. Wesley Baumgardner
Chief Biodynamics and Protection Division
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This report summarizes the initial testing of a new parachute slider reefing system to control the opening dynamics of the military C-9 parachute. It has been theorized that if one could control the opening of the parachute canopy used during emergency ejections, the parachute opening forces on the crewmember could be significantly reduced. The report addressed the reefing system modification and summarizes the initial testing results of the new slider reefing system to control the parachute opening dynamics.

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DEVELOPMENT AND TESTING OF A NEW REEFING SYSTEM TO REDUCE PARACHUTE OPENING SHOCK CHARACTERISTICS DURING SEAT EJECTION

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ABSTRACT As the speed of today's aircraft continues to increase, so does the difficulty of returning the pilots safely to the ground. To improve the safety of the pilot during seat ejection, the parachute's deceleration forces need to be reduced. It has been theorized that if one could control the opening of the canopy, the forces seen by the pilot could be significantly reduced. Initial testing has been completed on a new slider reefing system to control the opening dynamics. This paper will address the modification and the acceleration profiles of the new system.

INTRODUCTION To reduce the potential for injury during seat ejection, the opening force characteristics of the C-9 need to be addressed. The task is to reduce the forces by altering the reefing system. In 1972, the present reefing line system with pyrotechnic cutters was implemented to control the opening of the C-9. While the military parachute has remained the same, the sport parachute has changed dramatically. Today's sport parachute is a square, or gliding canopy. The square uses a slider to control the opening dynamics. Because of the mild opening characteristics, the square's are commonly jumped hundreds of times without injury to personnel or equipment. By adapting the technology of sport parachutes to the development of a new reefing system, the opening shock characteristics of the C-9

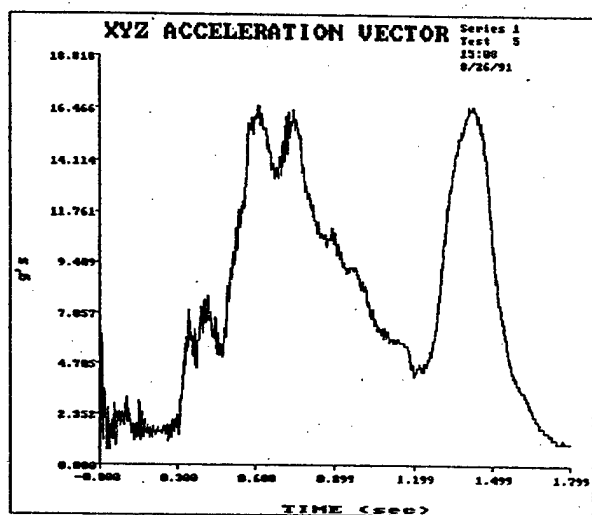
can be controlled. The slider reefing system will not only reduce the forces during opening, but will eliminate the need for the 11P12-15-7 Reefing Line Cutters.

METHODS When evaluating any modifications to the reefing system, a baseline of the standard ACES II configuration will be referenced. To produce non-biased results, the baseline data and any modification evaluations need to be performed using the same test conditions. To insure similar testing conditions from test to test while maintaining a cost effective means for testing, the Cylindrical Test Vehicle (CTV) has been developed. The CTV is used to evaluate parachute opening shock characteristics with various reefing systems. The developmental testing of the CTV is used to establish the criteria for the base line evaluation. Because of stability problems, the effective air speeds of the test vehicle are limited to 300, 375, and 450 feet per second. To simulate parachute deployment, the CTV deploys the ACES II headbox across the air stream, similar to the ejection seat. An onboard instrumentation system is used to determine effective air speed at deployment, the riser loads, the acceleration vector, and the altitude loss. An onboard camera provides video coverage during deployment.

RESULTS Three tests at the lower speeds and ten at the higher test speed have been completed to produce the baseline for any

modification to the ACES II reefing system. Figure one illustrates a typical acceleration profile for the ACES II reefing system during a high speed deployment.

Figure 1
C-9 with Standard ACES II Reefing System



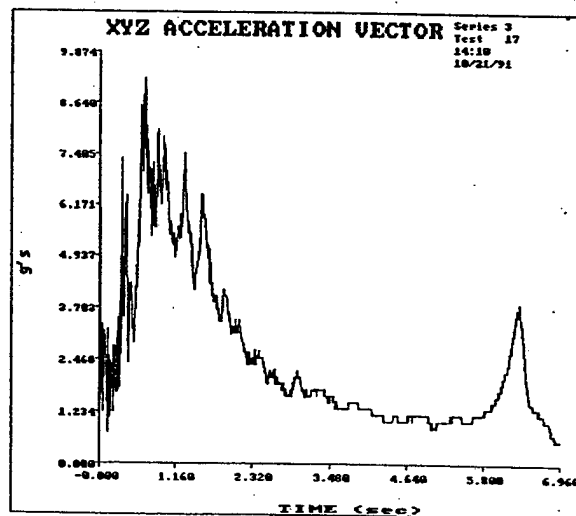
Test condition Air speed: 450 ft/sec.
CTV weight: 300 lbs.

Note in figure 1, the standard reefing system introduces dynamic pulsing. The energy is distributed into two large pulses. The first pulse averaged 15.9 g's and the second 14.5 g's thru the baseline testing. There are several means to improve the safety of the pilot by altering the general characteristics of the acceleration profile. A more desirable profile would distribute the energy in a single pulse with reduced magnitude while improving the altitude loss factor.

To provide an acceleration profile that will address these features, the reefing system would have to control the rate of the opening based on the tension in the suspension lines. On today's sport rig, the opening is controlled by a square slider. By varying the surface area and the shape of the slider, the sport jumpers can control the rate of the opening. Because of the speed and the nature of the C-9, a square slider may not allow the canopy to open. When adapting a slider to a round

canopy, you must allow air to pass thru the slider to inflate the canopy. The new system will eliminate the reefing line, and replace it with a ring slider. The slider will control the opening, by allowing the mouth to open based on the internal pressure differential. As the internal pressure increases, the force to open the mouth will cause the slider to move down the suspension lines. For the initial testing, a slider was constructed using a single 13 foot band around the mouth of the canopy. Seven grommets have been equally spaced around the ring. Four of the twenty eight suspension lines will pass thru each grommet. With the elimination of the slider's surface area, the slider will rely on a pressure differential to control its position on the suspension lines. Note in figure 2, it is feasible to reduce the amplitude by increasing the duration. Figure 2 illustrates the typical acceleration profile from a high speed deployment with the 13 foot ring slider.

Figure 2
C-9 with 13 Foot Ring Slider

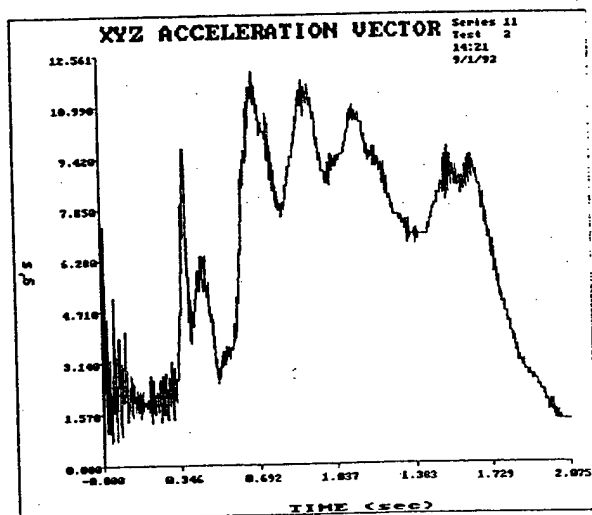


Test conditions Air speed: 450 ft/sec.
CTV weight: 300 lbs.

The amplitude for the first pulse with the line cutters has been reduced from 15.9 g's to an average of 9.6 g's for the 13 foot ring slider. Although the ring slider has reduced the loads, it has introduced an additional problem. The time interval

between first peak and the steady state descent rate has become unpredictable. By increasing the interval of time, the 13 foot slider has increased the altitude loss required to reach the steady state descent rate. To improve the general characteristics of the acceleration profile the time interval needs to be reduced. To reduce the interval from mortar fire to a full open condition, the size of the slider will be increased until a desirable profile is reached. Additional testing has been completed using a longer ring slider. The length of the slider has increased in fourteen inch increments until the slider reached the length of 21 feet. These tests were conducted to reduce the time interval between mortar fire and a steady state decent rate. Figure 3 illustrates the typical acceleration profile from a high speed deployment with the 21 foot ring slider.

Figure 3
C-9 with 21 Foot Ring Slider



Test conditions Air speed: 450 ft/sec.
CTV weight: 300 lbs.

Note in figure 3, the energy has been removed in a large pulse. The maximum g loads have been kept to 12 g's and the duration of the pulse has been increased. The 21 foot ring slider also reached the steady state decent rate while losing only 1000 feet of altitude from the time of deployment. This is comparable to the

average 1020 foot loss by the standard ACES II system.

Conclusion As the results of the test disclosed, the ring slider can reliably control the opening. Additional tests will be conducted to determine the effects of the ring slider as the size continues to increase. The length of the slider will be increased until it adversely effects the opening dynamics. At this point, the initial testing of the ring slider reefing system will be completed.

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